Leaf Injury Associated with Copper and Sulfur in Northern Grape Varieties: Preliminary Assessment

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Topics

- Role of copper and sulfur for disease control in grapes
- Forms of copper and sulfur, how they work, and how they injure plants
- Northern Grapes Project disease management research—preliminary findings
Copper and Sulfur

- Among the oldest fungicides and still among the most important
  - Homer refers to “pest-averting” quality of sulfur in 1000 BC
  - Bordeaux mix developed in 1800s, first used to control grape downy mildew
- Phytotoxicity has long been recognized as a problem
  - J.G. Horsfall, 1945: “Copper and sulfur may be expected to act unexpectedly”
Role of Copper and Sulfur in Managing Diseases of Grapes

• Copper-based fungicides
  – Highly effective on downy mildew pathogen
  – Limited activity against other pathogens

• Sulfur
  – Highly effective on powdery mildew
  – Little or no activity on other pathogens

• Liquid lime-sulfur
  – Dormant application may have eradicant activity on anthracnose fungus
Role of Copper and Sulfur in Managing Diseases of Grapes

• Fungicide resistance management
  – Both copper and sulfur act by non-specific disruption of proteins
  – Still effective after centuries of use
  – DMIs, strobilurins, and SDHIs can be overcome by a few mutations in pathogens → fungicide resistance
  – Some forms of copper and sulfur cheaper than synthetic fungicides
Role of Copper and Sulfur in Managing Diseases of Grapes

- Important in organic production
  - Some forms of copper and sulfur are approved by OMRI
  - Copper and sulfur often less expensive than other OMRI-approved products
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Factors Affecting Copper Efficacy and Phytotoxicity

- Amount of metallic (actual, elemental) copper
- Soluble vs. relatively insoluble (= fixed) forms
- Size of copper-containing particle or “grind”
- pH of solution
- Weather
Soluble vs. Insoluble Copper Fungicides

• Copper sulfate
  – Highly soluble in water
  – Even with relatively low amounts of copper, too much goes into solution too quickly → plant injury
  – Easily washed off by rain
Soluble vs. Insoluble Copper Fungicides

• “Fixed” copper
  – Low solubility in water
  – Spray mix is not a solution but rather a suspension of particles containing copper
  – Examples
    • Copper sulfate formulated with lime (e.g., Bordeaux), gypsum (e.g., Cuprofix), or hydroxyl ions (e.g., Basic Copper Sulfate) to raise pH, reduce solubility
    • Copper hyroxide (e.g., Champ, Kocide)
    • Copper oxychloride sulfate (e.g., COCS)
    • Copper oxide (e.g., Nordox)
    • Copper ammonium carbonate (e.g., Copper-Count N)
    • Copper lineolate (e.g., TennCop)
Size of Copper “Particle”

- Lots of product literature, and some research, suggest benefits of “micronized” particles
- Smaller particles provide more uniform coverage
• Smaller particles make copper more available, so lower rates can be used
  – Less environmental risk
  – More economical, only if smaller particles don’t cost a lot more than larger particles
• Less prone to wash off, therefore more persistent (which can be good or bad)
pH and Copper Solubility

- At lower pH, copper ions released from “fixed” fungicides more quickly
- Copper fungicides should not be mixed with phosphorous acid fungicides or any product that will reduce pH below 6.5
- Because some forms of copper are persistent, consider the interval between copper and PA fungicide sprays
Weather and Copper Injury

- Copper injury generally worse the longer leaves stay wet
  - Apply in lower volumes
  - Apply during dry weather
Info on Sulfur Fungicides

- *Strategic Use of Sulphur in Integrated Pest Management Programs for Grapevines*, Final Report to Grape and Wine Research and Development Corp. (Australia), by B. Emmet et al., 2003

- Wayne Wilcox’s Tome on Grape Disease Management: www.fruit.cornell.edu/grape/pdfs/Wilcox-Grape%20Disease%20Control%202012.pdf
Sulfur Fungicides

- Dust
- Lime sulfur—water soluble, highly potent
- Wettable—formulated with surfactants
- Liquid flowable—homogenized and suspended in water
- Micronized dry flowable—sulfur residues infused with water and dispersants to produce an emulsion, very fine particle size (1-8 μm)
Sulfur Efficacy

- Sulfur acts via contact and vapor activity
  - Contact activity increases as particle size decreases
    - Micronized dry flowable and liquid flowable (less than 8 μm) more effective than dusts (~25 μm)
    - Smaller particles are more rainfast
  - Contact activity is not temperature dependent
  - Vapor activity, in theory, is temperature dependent, but Wilcox et al. found similar control of PM at 59 °F as 82 °F
Sulfur Phytotoxicity

- In the presence of oxygen and water, sulfur converted to sulfuric acid on leaves

\[ S \rightarrow SO_2 \rightarrow SO_3 \rightarrow H_2SO_4 \]

- Injury more likely at temps > 85 °F within 2 hours of application; threshold temp may be lower in humid climates

- Greater risk of phytotoxicity if particles < 1 μm because S can enter stomata
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NGP Disease Research

• Plant Pathology objectives
  – Determine relative resistance of northern varieties to diseases
  – Determine relative sensitivity of northern varieties to copper and sulfur

• Collaborators
  – Kevin Iungerman—Cornell University
  – Lorraine Berkett—University of Vermont
  – Patricia McManus, Dean Volenberg, Matt Stasiak, Brian Schauske—University of Wisconsin
Crop injury warning for products containing difenoconazole: Inspire Super, Revus Top, Quadris Top
<table>
<thead>
<tr>
<th>Product (a.i.)</th>
<th>Rate per acre</th>
<th>Rate a.i. per acre</th>
<th>Dates applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Champ WG (copper hydroxide)</td>
<td>4 lb</td>
<td>3.1 lb copper hydroxide (= 2 lb copper)</td>
<td>May 22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>June 4 and 22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>July 4 and 18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>August 6</td>
</tr>
<tr>
<td>Microthiol Disperss (sulfur)</td>
<td>10 lb</td>
<td>8 lb sulfur</td>
<td>May 22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>June 4 and 22</td>
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<td></td>
<td></td>
<td></td>
<td>August 6</td>
</tr>
<tr>
<td>Inspire Super (difenoconazole + cyprodinil)</td>
<td>20 fl oz</td>
<td>0.114 lb difenoconazole</td>
<td>June 4 and 22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>July 4</td>
</tr>
</tbody>
</table>

Temperature at time of application < 70 F, except 79 F on July 4
Maximum daily temps < 82 F, except 90 F on July 4
Data Collection

- About every 2 weeks, vines assessed for injury
  1 = no visible injury
  2 = minor injury
  3 = moderate injury
  4 = severe injury
- Same person did ratings weekly season-long
- Second person did two ratings, as a check on first rater
Foch at Peninsular Station

Sprayed with sulfur

Sprayed with copper
Copper injury on Brianna
Preliminary Data
Sulfur toxicity on grape leaves at Sturgeon Bay, WI, 2012
1 = no injury; 4 = severe injury

Maximum daily temp

Brianna
Frontenac
Vignoles
Noiret
NY76
LaCrescent
Marquette
Leon Millot
LaCrosse
Foch
Copper toxicity on grape leaves at Sturgeon Bay, WI, 2012
1 = no injury; 4 = severe injury

- Brianna
- Frontenac
- Vignoles
- Noiret
- NY76
- LaCrescent
- Marquette
- Leon Millot
- LaCrosse
- Foch
Inspire (difenoconazole) toxicity on grape leaves at Sturgeon Bay, WI, 2012
1 = no injury; 4 = severe injury
Next Steps

• Repeat over years, sites, additional cultivars
• Your comments, suggestions welcome!
  – psm@plantpath.wisc.edu
  – (608) 265-2047
Copper and Sulfur Fungicides

- Inhibit fungi on surface of plants
- Mode of action probably by denaturating proteins
- Non-selective, so also denatures proteins in plants
- Plants somewhat protected by cuticle, bark
- Fungicidal efficacy vs. plant injury balancing act
2012 Research: Leaf sensitivity to copper, sulfur, and difenoconazole

- Peninsular Agricultural Research Station (Sturgeon Bay) vineyard established in 2008
- 10 varieties replicated 4 times
- Fungicides applied at about 2-week intervals with a handgun sprayer to “run-off”
- Vines observed season-long for injury and/or discoloration